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A TEST OF COMMERCIAL THINNING ON THE HEMLOCK EXPERIMENTAL FOREST

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This paper contains the partial results of a cooperative study by Oregon State University and the U.S. Forest Service.

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A TEST OF COMMERCIAL THINNING ON THE HEMLOCK EXPERIMENTAL FOREST

Reference Abstract

Hilt, Donald E., Francis R. Herman, and John F. Bell. 1977. A test of commercial thinning on the Hemlock Experimental Forest. USDA For. Serv. Res. Pap. PNW-225, 11 p., illus. Pacific Northwest Forest and Range Experiment Station, Portland, Oregon.

During 11- to 12-year treatment periods, beginning at ages 49 to 55, low and high commercial thinnings, at 3- and 6-year intervals, improved diameter growth of residual trees. Gross merchantable growth per acre apparently was not reduced by thinning. Thinning had no appreciable effect on mortality.

KEYWORDS: Thinning (commercial), commercial thinning, growth response, yield (forest), western hemlock, *Tsuga heterophylla*, Washington (Hemlock Experimental Forest), Hemlock Experimental Forest--Washington.

RESEARCH SUMMARY

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Commercial thinnings in a 50-year-old stand of pure, well-stocked, even-aged western hemlock (*Tsuga heterophylla* (Raf.) Sarg.) on the Hemlock Experimental Forest near Hoquiam, Washington, began in 1952 and ended in 1969. The experiment tested high and low thinnings, both at 3- and 6-year intervals. Volumes removed in thinning ranged from 52 to 107 percent of the gross merchantable cubic volume increment accrued during the experiment.

Compared to the control areas, thinning increased the average diameter growth rate of remaining trees. Merchantable gross growth apparently was not reduced by thinning. The efficiency of the residual growing stock was increased, as growth percent was higher in thinned stands. Thinning had no appreciable effect on mortality. The repeated thinnings, however, did salvage much of the merchantable mortality that would otherwise have been lost.

INTRODUCTION

This study on the Hemlock Experimental Forest[1] was an investigation of growth and yield of 50-year-old western hemlock (*Tsuga heterophylla* (Raf.) Sarg.) commercially thinned several times. The Forest is located in Grays Harbor County, Washington, 10 miles north of Hoquiam (fig. 1). The stand when first thinned in 1952 was nearly pure western hemlock with less than 10 percent (by cubic volume) Sitka spruce (*Picea sitchensis* (Bong.) Carr.) and Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco). The treatments were a series of high and low thinnings at 3- and 6-year intervals in well-stocked, even-aged hemlock. A cost analysis, which is essential for the final evaluation of efficiency of different thinning regimes, is not contained in this paper.

[1] The Hemlock Experimental Forest was established in 1949 as a cooperative research effort of the St. Regis Paper Company and the USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon.

There are few published reports dealing with commercial thinnings in older stands of western hemlock. A 5-year growth study by Warrack (1960) in a 60-year-old stand in British Columbia revealed that basal area growth was nearly the same for thinned stands as it was for unthinned stands.

A progress report prepared by Staebler (1957) investigated initial responses to thinning on the Hemlock Experimental Forest. This interim report compared high and low thinnings at 3-year intervals, after two repeated thinnings, with an unthinned area. The ratio of gross growth to growing stock (growth percent) was larger in the thinned areas, with high thinning having the largest growth percent. Realized increment (volume harvested in thinning plus the volume added to growing stock) showed a pronounced advantage for thinning. This was due primarily to mortality being salvaged in the thinned areas.

Williamson (1966) recorded the d.b.h. growth of 60-year-old trees in a nearby shelterwood study on the Hemlock Experimental Forest. He found

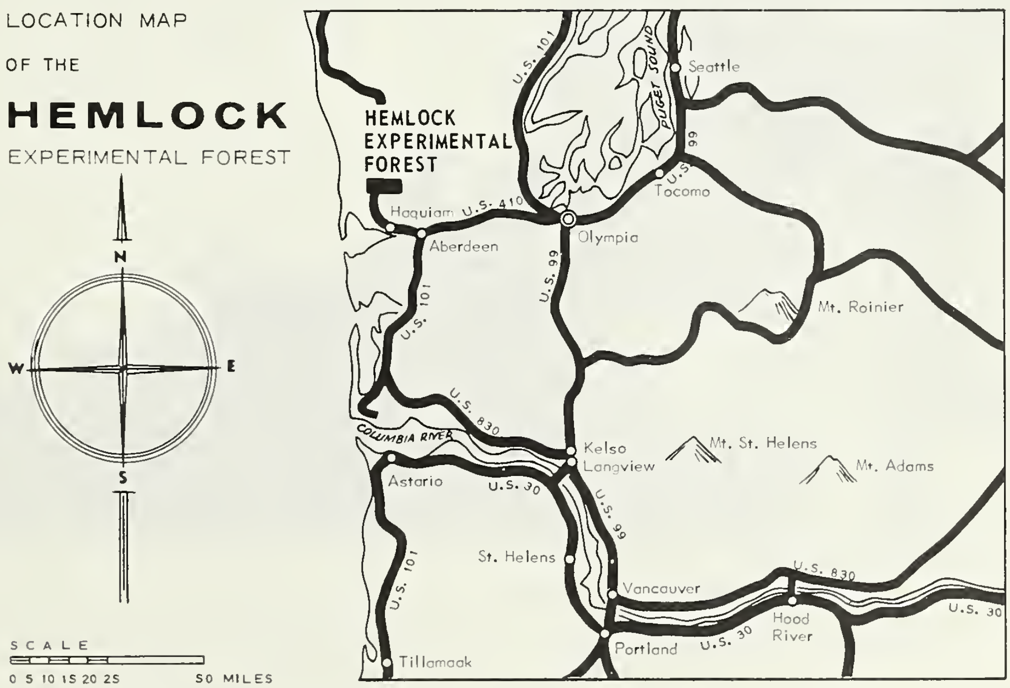

Figure 1.--Location of the Hemlock Experimental Forest.

that the diameter increment of dominant and codominant trees in areas with less than 80 trees per acre (198 per ha) was almost twice that of comparable trees in lightly cut stands.

A 17-year thinning study in southwest Alaska revealed that a 96-year-old stand of western hemlock and Sitka spruce responded well to thinning (Farr and Harris 1971). Thinning increased diameter increment on the residual trees and also removed many trees that would have died during the 17-year period.

METHODS

DESIGN OF STUDY

Treatments were laid out in compartments[2/] A, B, and C as follows (fig. 2):

Treatment	Thinning method and interval
A-1	Low, 3 years
A-2	Unthinned control
A-3	Low, 6 years
B-1	High, 3 years
B-2	Unthinned control
B-3	High, 6 years
C-1	High, 3 years
C-2	Unthinned control
C-3	Low, 6 years
C-4	High, 6 years
C-5	Low, 3 years

Treatments in compartments A and B were 15 to 25 acres (6 to 10 ha) in size, and treatments in compartment C were 5 to 6 acres (2 to 2.4 ha).

Thinning specifications called for the removal of 85 percent of the gross merchantable cubic-foot[3/] increment for

[2/] Compartment is a convenient term for referring to these larger treatment units.

[3/] Cubic-foot volume to 4-inch (10-cm) top excluding stump. Trees larger than 5.5-inch (14-cm) d.b.h.

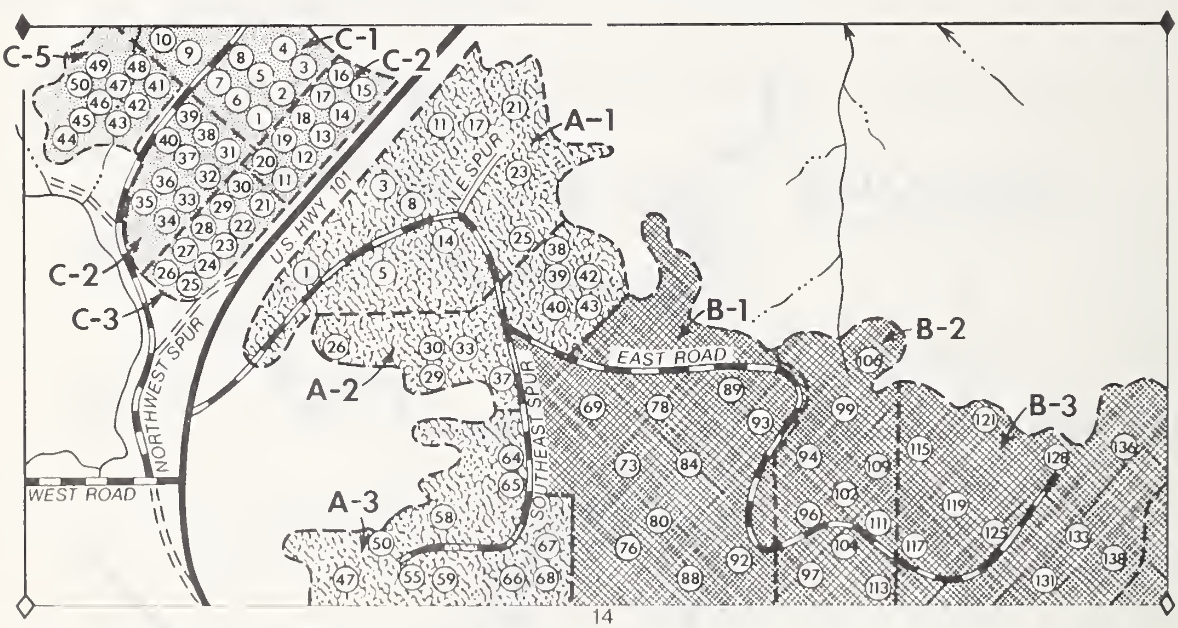

Figure 2.--Field layout of thinning treatments (N 1/2 sec. 14, T. 19 N., R. 10 W., W. M.).

the 3- or 6-year period at each thinning. The goal was to remove trees that averaged 3 inches below average stand d.b.h.[4] for low thinnings, and 3 inches above average stand d.b.h. for high thinnings.

Some thinnings were not made precisely at the 3- or 6-year intervals. Also, treatment periods were different for the three compartments (figs. 3a and 3b).

The original experimental design was not followed, and the originally-planned statistical comparisons could not be made. Each treatment should be compared *only* to the unthinned control in the corresponding compartment. Even though there are essentially three distinct experimental compartments, any gross differences due to thinning should be apparent.

[4] Average diameter is the diameter of the tree of average basal area for trees larger than 5.5-inch (14-cm) d.b.h.

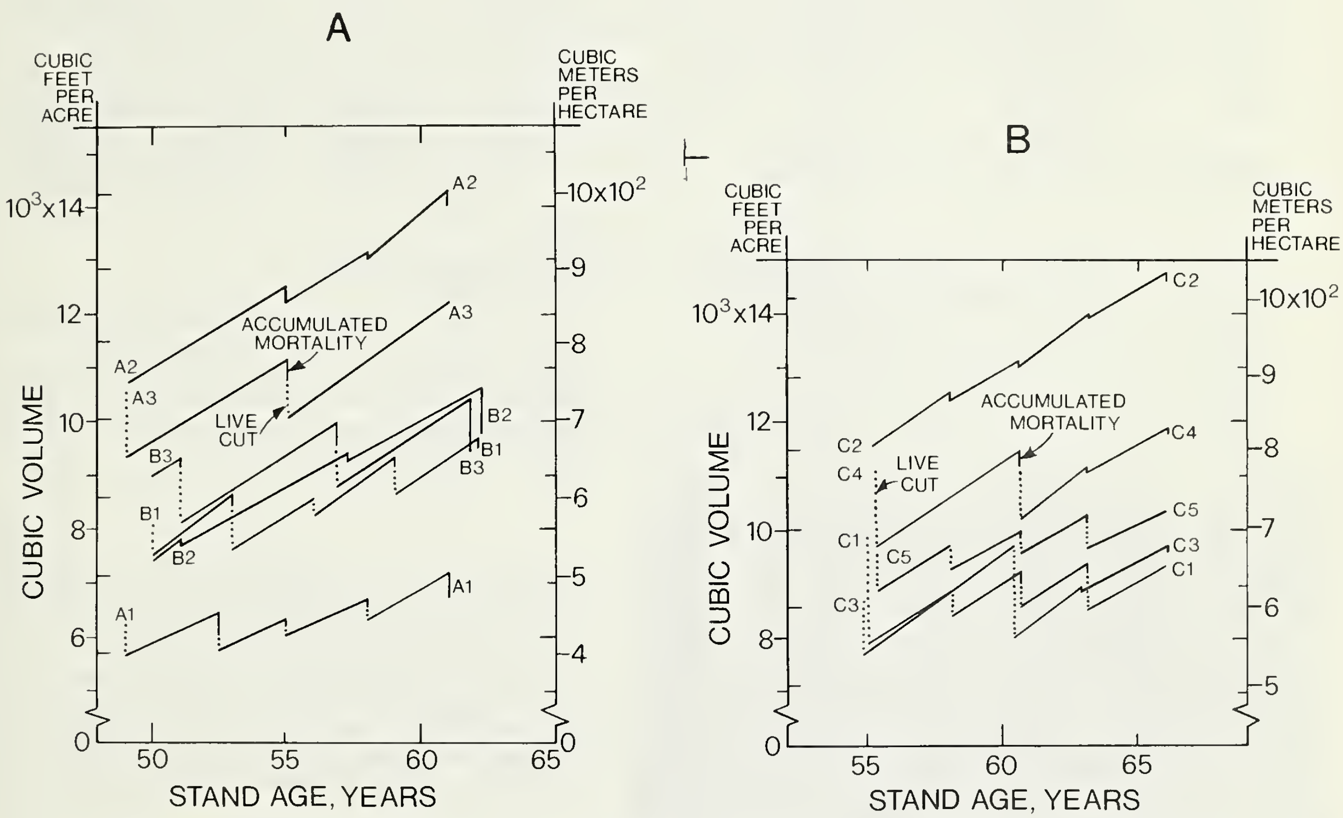

Figure 3a and 3b.--Severity of thinnings (cubic volume to 4-inch (10-cm) top, trees larger than 5.5-inch (14-cm) d.b.h.)

MEASUREMENTS

Measurements were recorded on 10 permanent sample plots in each treatment prior to thinnings. Concentric 1/40-acre (101-m^2) and 1/10-acre (905-m^2) circular plots were systematically located. All trees larger than 5.5-inch (14-cm) d.b.h. were tallied on the 1/10-acre plot, and trees larger than 1.5-inch (4-cm) d.b.h. were tallied on the 1/40-acre plot. Measured trees were tagged, and their diameters were recorded to the nearest 0.1 inch (2.5 mm) at each measurement. Heights were measured on selected trees in 1952, 1959, and 1968. Additional silvicultural data such as crown class and tree damage were also recorded for each tree.

DETERMINATION OF VOLUME AND VOLUME GROWTH

Cubic volume to a 4-inch (10-cm) top excluding stump for trees larger than 5.5-inch (14-cm) d.b.h. was used to analyze growth and yield because the experiment consisted of *commercial* thinnings, with control of thinnings based only on trees larger than 5.5-inch (14-cm) d.b.h. Sound tree volumes were used since little defect was present.

Volumes were assigned to individual trees according to the Comprehensive Tree-Volume Tarif Tables (Turnbull et al. 1972). Actual calculations were performed with the computerized tarif equations (Brackett 1973). Tarif numbers were determined in each compartment for the base periods of 1952, 1959, and 1968 when sample heights were taken. Appropriate tarif numbers for each measurement were determined by linear interpolation between these base periods. Plot volumes were multiplied by the necessary expansion factors to arrive at total volumes per acre.

The two measures of growth used in this paper, gross growth and realized growth, are defined by the following equations (Husch et al. 1972):

$$\Delta V_{gross} = V_{end} - V_{initial} + V_{cut} + V_{mortality}$$

$$\Delta V_{realized} = V_{end} - V_{initial} + V_{cut} + V_{mortality\ cut}$$

Both measures of growth include ingrowth and also growth on trees that later died or were cut. Ingrowth accounted for a negligible part of the gross or realized growth during the experiment.

STUDY AREA

The Hemlock Experimental Forest lies on gentle to medium slopes at elevations of 225 to 410 feet (70 to 127 m). Both climate and soil are favorable for rapid tree growth. Average annual rainfall is 100 inches (254 cm) with 20 to 25 inches (51 to 64 cm) falling during the growing season (Dimock and Herman 1963). Snow accounts for only a small percentage of the total precipitation. Long term average annual temperature is 50°F (10°C), with an average growing-season temperature of 56°F (13°C). There are occasional periods of freezing temperatures during the winter months. Hoquiam clay loam, a moderately deep, well-drained forest soil, covers almost the entire experimental area.

PRE-TREATMENT STAND

The pure, even-aged western hemlock stand originated in 1903 after old-growth logging. A few scattered trees remained from the original old-growth stand, many of which were poor quality and infected with mistletoe (Staebler 1957). Some were cut in thinning and their removal favored remaining trees.

Initial stand characteristics varied considerably for the various treatments (table 1). Treatment A-1 contained fewer trees and less cubic volume (57 percent) than its control, A-2. Treatment B-2 had considerably fewer trees than other treatments in compartment B. Treatment C-3 had more smaller trees than its control C-2, resulting in a lower averaged d.b.h. in treatment C-3.

Large trees remaining from the original old-growth stand accounted for part of the variation in average d.b.h. between treatments.

Site index for all treatments averaged 157 feet (49 m) at 100 years, a low site class II, based on Barnes' (1962) revised site index curves.

Variations in site index and stand structure account for part of the differences between initial stand characteristics and also tended to mask the real effects of thinning. Gross differences caused by thinning were apparent over the length of the treatment periods (11-12 years).

Table 1--*Descriptive characteristics of treatments before thinning*

Treatment, thinning method, and interval	Year	Age	Trees per acre	Average d.b.h.[1/]	Merchantable volume per acre[2/]
		Years	Number[3/]	Inches[4/]	Cubic feet[5/]
A-1 Low, 3 years	1952	49	195	12.06	6,182.1
A-2 Control	1952	49	275	13.26	10,760.5
A-3 Low, 6 years	1952	49	252	13.74	10,670.4
B-1 High, 3 years	1953	50	259	12.59	8,155.1
B-2 Control	1953	50	169	14.78	7,433.0
B-3 High, 6 years	1953	50	260	13.20	8,966.0
C-1 High, 3 years	1958	55	282	12.65	9,837.7
C-2 Control	1958	55	250	14.38	11,540.9
C-3 Low, 6 years	1958	55	330	11.18	8,697.9
C-4 High, 6 years	1958	55	265	13.88	11,331.4
C-5 Low, 3 years	1958	55	237	13.55	9,611.4

1/ Trees larger than 5.5-inch (14-cm) d.b.h.

2/ Cubic-foot volume to 4-inch (10-cm) top excluding stump. Trees larger than 5.5-inch (14-cm) d.b.h.

3/ Trees per hectare = trees per acre X 2.47.

4/ Centimeters d.b.h. = inches d.b.h. X 2.54.

5/ Cubic meters per hectare = cubic feet per acre ÷ 14.29.

SEVERITY OF THINNINGS

Standing cubic volumes at the end of the experiment were greater than initial volumes for all treatments except C-1 (figs. 3a and 3b). Cubic volume of growing stocks was increased by 12, 11, and 4 percent for thinned treatments in compartments A, B, and C, compared to 31, 30, and 27 percent for their respective controls.

Thinnings were light by present day standards (fig. 4). An average of 79 percent of the gross cubic-foot increment was thinned in compartment C, while averages of 53 and 54 percent were removed in compartments A and B, respectively. Thinnings removed 107 percent of the gross increment in treatment C-1. These figures also indicate that thinnings in compartments A and B were much lighter than the original proposal to remove 85 percent of the gross cubic-foot increment. Because considerable care was taken to approximate the "85-percent" thinning goal, results further indicate the difficulty in accurately attaining such thinning control.

Figure 4.--A 60-year-old western hemlock stand (treatment C-5) after second low thinning at 3-year intervals.

STAND DEVELOPMENT

MORTALITY

Mortality accounted for 18, 27, and 9 percent of the gross merchantable growth for compartments A, B, and C

Table 2--*Merchantable*[1/] *cubic volume growth and yield for entire experiment*

Treatment, thinning method, and interval	Treatment period	Initial volume	Ending volume	Live cut	Total mortality[2/]	Mortality cut	Gross increment	Gross p.a.i.[3/]	Growth percent[4/]
	- - - - - -	- - - - - -	- - - - - -	- - - - - -	Cubic feet per acre[5/]	- - - - - -	- - - - - -	- - - - - -	- - - - - -
A-1 Low, 3 years	1952-1964	6,182.1	6,696.2	1,597.9	848.2	254.7	2,960.2	246.7	3.96
A-2 Control	1952-1964	10,760.5	14,089.5	0.0	682.5	0.0	4,011.5	334.3	2.72
A-3 Low, 6 years	1952-1964	10,670.4	12,255.2	2,045.1	312.1	243.3	3,942.0	328.5	3.09
B-1 High, 3 years	1953-1965	8,155.1	9,551.1	2,325.2	465.9	235.2	4,187.1	348.9	4.12
B-2 Control	1953-1965	7,433.0	9,674.3	0.0	1,161.9	0.0	3,403.2	283.6	3.22
B-3 High, 6 years	1953-1965	8,966.0	9,475.8	2,014.8	1,318.0	224.8	3,842.6	320.2	3.58
C-1 High, 3 years	1958-1969	9,837.7	9,316.4	3,611.4	279.1	66.7	3,369.2	306.3	3.49
C-2 Control	1958-1969	11,540.9	14,638.2	0.0	364.8	0.0	3,462.1	314.7	2.39
C-3 Low, 6 years	1958-1969	8,697.9	9,657.8	2,459.8	276.1	0.0	3,695.8	336.0	3.81
C-4 High, 6 years	1958-1969	11,331.4	11,843.3	2,631.2	434.2	0.0	3,577.3	325.2	3.02
C-5 Low, 3 years	1958-1969	9,611.4	10,377.3	1,915.9	187.9	48.1	2,869.7	260.9	2.69

1/ Cubic-foot volume to a 4-inch (10-cm) top excluding stump. Trees larger than 5.5-inch (14-cm) d.b.h.

2/ Includes mortality cut.

3/ Gross periodic annual increment = gross increment ÷ number of years in treatment period.

4/ Percent of average volume present during experiment.

5/ Cubic-meter volume per hectare to a 10-cm top = cubic-foot volume per acre to a 4-inch top ÷ 14.29.

(table 2, column 6). Most of the merchantable volume lost to mortality resulted from two climatic disturbances. A heavy, wet snow that fell during the latter half of January 1954 caused some breakage of tall, slender trees in compartments A and B (Staebler 1957a). The 1962 Columbus Day windstorm caused considerable blowdown of larger trees. Thinning apparently did not have much effect on the volume lost to mortality since storm damage was erratic and unrelated to the type of thinning.

Suppression caused the death of some smaller trees. Although control areas A-2 and C-2 lost more trees to suppression than other treatments in their compartments, there was not enough evidence to conclude that thinning had any appreciable effect on forestalling mortality due to suppression.

NUMBER OF TREES

The number of live trees thinned was consistent with the initial stocking levels and types of thinning applied (table 3). Fewer, but larger, trees were removed in high thinnings than in low thinnings. Erratic storm damage accounted for much of the variation in the number of trees lost to mortality.

AVERAGE DIAMETER

Low thinnings removed trees that were less than the average d.b.h. on all compartments, and high thinnings removed trees larger than the average stand d.b.h. (table 4). In general, thinnings removed larger trees than did mortality. The slight increase in average d.b.h. for mortality in some treatments was due to the death of larger trees during the two climatic disturbances.

The results of thinnings cannot be evaluated properly unless consideration is given to the sizes of the trees produced rather than merely to the volume they represent (Smith 1962). The most common method of testing different treatments is to compare their average diameters. This method is adequate if the comparisons are made between equal numbers of crop trees per acre. For this reason, the average diameter growth for the largest surviving 40 trees per acre (4 per 1/10-acre plot) was used (table 4). Selecting the largest 40 trees per acre is commensurate with the European density standard of 100 trees per hectare. These trees were all dominants or codominants--complete release of some of these trees

Table 3--*Number of trees greater than 5.5-inch (14-cm) d.b.h. per acre before and after thinnings, removed in thinnings, and mortality*

Treatment, thinning method, and intervals	Treatment period	Before thinning	Live cut	Mortality	After thinning
		Number[1/] per acre			
A-1 Low, 3 years	1952-1964	195	71	35	97
A-2 Control	1952-1964	275	--	42	233
A-3 Low, 6 years	1952-1964	252	77	26	149
B-1 High, 3 years	1953-1965	259	49	35	191
B-2 Control	1953-1965	169	--	29	144
B-3 High, 6 years	1953-1965	260	39	51	178
C-1 High, 3 years	1958-1969	282	56	22	208
C-2 Control	1958-1969	250	--	31	223
C-3 Low, 6 years	1958-1969	330	86	21	246
C-4 High, 6 years	1958-1969	265	44	27	198
C-5 Low, 3 years	1958-1969	237	78	15	152

[1/] Number trees per hectare = number trees per acre X 2.47.

Table 4--*Average breast high diameters of all trees greater than 5.5-inch (14-cm) d.b.h. and 40 largest trees per acre, before and after thinning, removed in thinning, and mortality*

Treatment, thinning method, and interval	Treatment period	Trees > 5.5-inch d.b.h. Average d.b.h.				Forty largest trees per acre Average d.b.h.[1/]		
		Before thinning	Cut	Mortality	After thinning	Before thinning	After thinning	p.a.i.[2/]
		Inches[3/]				Inches[3/]		
A-1 Low, 3 years	1952-1964	12.06	10.25	10.36	16.34	17.16	20.33	0.26
A-2 Control	1952-1964	13.26	--	8.96	15.36	20.09	22.23	.18
A-3 Low, 6 years	1952-1964	13.74	11.07	8.07	17.75	20.82	23.22	.20
B-1 High, 3 years	1953-1965	12.59	14.74	8.50	14.30	17.95	20.81	.24
B-2 Control	1953-1965	14.78	--	13.27	16.39	21.46	23.20	.16
B-3 High, 6 years	1953-1965	13.20	15.42	10.89	14.72	19.03	21.36	.21
C-1 High, 3 years	1958-1969	12.65	16.60	8.14	13.58	18.22	20.70	.23
C-2 Control	1958-1969	14.38	--	7.91	16.21	22.46	24.44	.18
C-3 Low, 6 years	1958-1969	11.18	11.43	8.28	12.80	17.09	19.26	.20
C-4 High, 6 years	1958-1969	13.88	16.09	9.01	15.52	19.85	22.26	.22
C-5 Low, 3 years	1958-1969	13.55	10.68	8.16	16.53	22.35	24.38	.18

1/ D.b.h. of 4 largest surviving trees per plot (a density of 40 per acre = 100 per hectare).

2/ Periodic annual increment in inches d.b.h.

3/ Centimeters d.b.h. = inches d.b.h. X 2.54.

probably did not occur until late in the experiment. Periodic annual increment for average diameter was larger for all thinned treatments compared to their respective controls (table 4). This is an excellent indication that thinning redistributed the growth to the larger trees.

GROWTH AND YIELD

Totals for Experiment

Summaries of the growth and yield of the various treatments for the entire experiment are presented in table 2. The treatment period was different among compartments A, B, and C, hence treatments should be compared only to the unthinned control in the corresponding compartment.

Thinning apparently did not reduce gross growth relative to the unthinned stands. When gross increment is expressed as a percent of initial volume, the growth on the thinned treatments was nearly the same or greater than their respective controls. Cubic volume growth for the experiment averaged 42, 47, and 35 percent of the initial volumes for the thinned treatments in compartments A, B, and C, compared to 37, 46, and 30 percent for their respective controls.

Statistical tests (unpaired t-tests) between thinned treatments and the control on compartment C showed no significant differences in growth. Gross growth on each of the 10 plots for each treatment, expressed as a percent of initial volume, were used as the test observations. No additional statistical tests were made because of inadequate experimental design.

Growth percent, the ratio of gross growth to growing stock, provides a measure of efficiency of residual growing stock. It is one of the most effective measures for comparing treatment effects when initial volumes are different. Growth percent was higher on all thinned treatments relative to their controls (table 2, column 10). This is another good indication that growth was adequately transferred to the residual stands after thinning. Some of the increase in growth percent, however, is due to the less efficient trees being removed (Reukema 1972).

There were no consistent advantages revealed for low thinning versus high thinning nor for light thinning versus heavy thinning.

Trends in Periodic Growth

The trends in periodic growth did not appear to be related to either the type of thinning or level of growing stock. Changes in growth rates for thinned treatments were similar to their respective control areas (figs. 3a and 3b). In response to above-average rainfall in 1963 and 1964, periodic increment increased for most treatments over the measurement period that spanned these 2 years.

Realized Volume

One of the major objectives of thinning is to utilize all of the merchantable material produced by the stand during the rotation (Smith 1962). Realized increment, which is the volume harvested in thinning plus the volume added to growing stock, showed an advantage for thinning (table 5). This is because repeated thinnings at frequent intervals salvage merchantable mortality that would have otherwise been lost.

Not much of the mortality was salvaged on treatments A-1 and B-3 because the thinning experiment ended for these treatments just after the Columbus Day windstorm of 1962. Most of the large trees lost to mortality during this storm would have been salvaged if thinnings had been continued.

The size of the mortality trees that were salvaged was not related to the type of thinning. High thinning salvaged smaller trees, just as low thinning did. Also, low thinning salvaged the larger trees lost to climatic disturbances.

Total realized volumes produced by each treatment for the entire experiment are also listed in table 5. As noted previously, treatment periods were of different lengths for compartments A, B, and C. Total realized volume is the ending volume plus live cut and mortality cut. This figure represents the total merchantable production for each treatment if it were logged at the ending date. Total realized volume, expressed as a percent of initial volume, indicates an advantage for thinning in all compartments.

Table 5--*Merchantable*[1] *cubic volume realized increment and total realized volume*

Treatment, thinning method, and interval	Treatment period	Gross increment	Realized increment	Realized, percent of gross	Realized volume	
		Cubic feet per acre[2]		Percent	Cubic feet per acre[2]	Percent[3]
A-1 Low, 3 years	1952-1964	2,960.2	2,366.7	80	8,548.8	138
A-2 Control	1952-1964	4,011.5	3,329.0	83	14,089.5	131
A-3 Low, 6 years	1952-1964	3,942.0	3,873.2	98	14,543.6	136
B-1 High, 3 years	1953-1965	4,187.1	3,956.4	94	12,111.5	149
B-2 Control	1953-1965	3,403.2	2,241.3	66	9,674.3	130
B-3 High, 6 years	1953-1965	3,842.6	2,749.4	72	11,715.4	131
C-1 High, 3 years	1958-1969	3,369.2	3,156.8	94	12,994.5	132
C-2 Control	1958-1969	3,462.1	3,097.3	89	14,638.2	127
C-3 Low, 6 years	1958-1969	3,695.8	3,419.7	93	12,117.6	139
C-4 High, 6 years	1958-1969	3,577.3	3,143.1	88	14,474.5	128
C-5 Low, 3 years	1958-1969	2,869.7	2,729.9	95	12,341.3	128

[1] Cubic-foot volume to a 4-inch (10-cm) top excluding stump. Trees larger than 5.5-inch (14-cm) d.b.h.

[2] Cubic-meter volume per hectare to a 10-cm top = cubic-foot volume per acre to a 4-inch top ÷ 14.29.

[3] Percent of initial volume.

DISCUSSION AND CONCLUSIONS

The considerable differences in initial stand characteristics for controls versus thinned stands, plus the failure to follow the original experimental design specifications, prevent obvious and sensitive comparisons. Results, however, appear to show that thinning on the Hemlock Experimental Forest satisfied the two fundamental objectives of thinning (Smith 1962): (1) the growth of the stand was adequately redistributed to the residual stand after thinning, and (2) nearly all of the merchantable material produced by the stand was utilized. Thinning increased the average diameter growth rate compared to the control areas. Merchantable gross growth apparently was not reduced by thinning. When the growth was expressed as a percent of the average volume present (growth percent), thinned treatments showed an avantage over the control areas. The efficiency of the residual growing stock was apparently increased by thinning. Thinning had no appreciable effect on mortality. The repeated thinnings, however, did salvage most of the merchantable mortality that would have otherwise been lost. This fact is reflected in higher realized increments and total productions (expressed as a percent of initial volume) for the thinned treatments compared to their control areas.

Although thinning in general revealed distinct advantages over unthinned control areas, there was no conclusive evidence that any one particular thinning treatment was any better than another.

Forest and land managers should remember that young western hemlock actually out-produces young Douglas-fir in net yield per acre on many sites (Dimock 1958). They must evaluate both silvicultural information and logging economics if they are to develop appropriate commercial thinning specifications. Extension of these study results, together with other available commercial thinning information, gives managers of young western hemlock forests another facet of knowledge to help them make thinning decisions.

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KEYWORDS: Thinning (commercial), commercial thinning, growth response, yield (forest), western hemlock, *Tsuga heterophylla*, Washington (Hemlock Experimental Forest), Hemlock Experimental Forest--Washington.

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